COST AND PERFORMANCE REPORT

EXECUTIVE SUMMARY

This report presents cost and performance data for a soil vapor extraction (SVE) system at the Tank 2 Operable Unit, Sacramento Army Depot (SAAD) Superfund site in Sacramento, California. SVE was used at the Tank 2 Operable Unit to treat soil contaminated with volatile organic compounds (VOCs).

The Tank 2 Operable Unit at SAAD was the location of an underground storage tank (Tank 2) used to store waste solvents. Release of waste solvents from the tank to the surrounding subsurface was suspected. The results of a subsequent remedial investigation (RI) indicated that approximately 650 cubic yards of soil surrounding Tank 2 were contaminated. Ethylbenzene, 2-butanone, tetrachloroethene, and xylenes were the primary constituents detected in soil at levels ranging from 0.005 to 11,000 mg/kg.

A Record of Decision (ROD) addressing the Tank 2 Operable Unit was signed in December 1991 and specified soil cleanup levels for ethylbenzene, 2-butanone, tetrachloroethene, and xylenes. The ROD also specified that these cleanup levels must be achieved within six months of system operation, as verified by confirmatory soil sampling. SVE was selected for remediating soil in the Tank 2 Operable Unit because it was determined to be the most cost effective of the remedial alternatives considered.

The SVE system used for this application consisted of eight vacuum extraction wells, a positive-displacement blower, a vapor-liquid separator, and primary and secondary carbon adsorption units.

The system was operated for approximately 102 days from August 6, 1992 until January 21, 1993. During that time, approximately 2,300 total pounds of VOCs were removed. Confirmatory soil boring data, collected in March 1993, indicated that the soil cleanup levels specified in the ROD were achieved for this application.

A problem encountered during this treatment application was the unexpected extraction of significant amounts of Freon 113 (approximately 1,800 pounds of the total 2,300 pounds of total VOCs removed consisted of Freon 113). The presence of Freon 113 in soil at the Tank 2 Operable Unit was not identified during the RI prior to system operation and required the use of additional carbon.

The total costs for this application, excluding costs for construction management and Title II services, were $556,000. These costs were higher than originally estimated. This was attributed to the presence of Freon 113 which caused the quantity of carbon required for this application to exceed the original estimate. The actual total cost was adjusted to show a calculated cost for treatment of soil without including the costs attributed to the Freon. The adjusted cost was $290,000, which corresponds to $450/cubic yard of soil treated.

SITE INFORMATION

Identifying Information

Sacramento Army Depot
Sacramento, California
Operable Unit # 3 (Tank 2)
CERCLIS # CA0210020780
ROD Date: 12/9/91

Treatment Application

Type of Action: Remedial
Treatability Study Associated with Application? Computer model of SVE
EPA SITE Program Test Associated with Application? No
Operating Period: 8/6/92 - 1/21/93
Quantity of Soil Treated During Application: 650 cubic yards (as reported by the vendor, consisting of an area 25 by 35 feet by 20 feet deep)

SITE INFORMATION (CONT.)

Background

Historical Activity That Contributed to Contamination at the Site: Metal-plating and painting operations, leaking underground storage tank

Corresponding SIC Codes:

3471: Electroplating, Plating, Polishing, Anodizing, and Coloring

3479: Coating, Engraving, and Allied Services, Not Elsewhere Classified

Waste Management Practice that Contributed to Contamination: Underground Storage Tank

Site History: The Sacramento Army Depot (SAAD) is a 485-acre U.S. Army support facility, located in Sacramento, California, as shown on Figure 1. Current and historical operations conducted at the facility include electro-optics equipment repair, emergency manufacturing of parts, shelter repair, metal plating and treatment, and painting. In conjunction with these operations, the Army maintains unlined oxidation lagoons and burn pits, a battery disposal area, areas designated for mixing pesticides, and a firefighter training area. [1]

In 1978 and 1979, the U.S. Army Toxic and Hazardous Materials Agency (USATHMA) identified several areas at SAAD, based on historical data, where the use, storage, treatment, and disposal of toxic substances may have contributed to contamination of soil and/or groundwater. In 1981, the Army and the California Central Valley Regional Water Quality Control Board (CVRWQCB) conducted investigations of soil and groundwater in the areas identified by USATHMA. The groundwater under the southwest corner of SAAD was determined to be contaminated with volatile organic compounds (VOCS) with the burn pits suspected as the main source of groundwater contamination. These investigations also identified six other potential areas of contamination (Figure 2): the Tank 2 area, the oxidation lagoons, the Building 320 leach field, the pesticide mix area, the firefighter training area, and the battery disposal well. Operable units were defined for each of these areas of

Figure 1. Site Location

contamination. The groundwater contamination was addressed in a 1989 Record of Decision (ROD) and the other operable units will be addressed in subsequent RODs. [1]

The Tank 2 Operable Unit was addressed in a 1991 ROD as Operable Unit #3 and is the subject of this report. As shown on Figure 2, the Tank 2 Operable Unit is located approximately at the center of the SAAD facility. This operable unit previously contained a 1,000-gallon underground storage tank (UST) used to store waste solvents until 1980. The UST, which was emptied in 1980 and removed in 1986, showed signs of deterioration indicating a possible release to the subsurface. The Army subsequently contracted Kleinfelder, Inc. to conduct a remedial investigation (RI) and an operable unit feasibility study (OUFS) to determine the extent of contamination and identify alternatives for cleaning up soil at the Tank 2 Operable Unit. The results of the RI indicated that the soil around the UST was contaminated with VOCs but that the VOCs had not migrated to the groundwater. Ethylbenzene, xylenes, 2-butanone, and tetrachloroethene were the primary contaminants detected during the RI. Figures 3 and 4

SITE INFORMATION (CONT.)

Background (cont.)

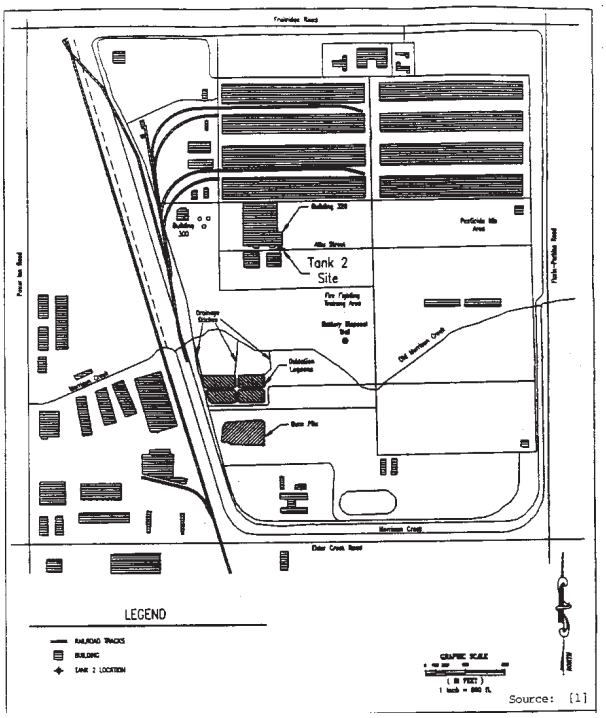

Figure 2. Site Layout [1]

show the location of soil contamination in a plan view and cross section of the Tank 2 Operable Unit. The results of the OUFS, completed in 1991, indicated that soil vapor extraction (SVE) was the most appropriate technology for remediating soil in the Tank 2 Operable Unit [1].

Regulatory Context: During the 1980s, EPA and the California Department of Health Services (DHS) became involved in the investigations conducted at SAAD by the U.S. Army and the CVRWQCB. The SAAD facility was subsequently placed on the National Priorities List (NPL) on August 21, 1987. In 1988, the U.S. Army, EPA, and the State of California entered a Federal Facilities Agreement (FFA). Under the FFA, the U.S. Army was the lead agency responsible for implementing the environmental response activities at SAAD.

A ROD, signed in 1991, specified treatment of soil using SVE, dehumidifying the contaminated air stream using a moisture separator, treating the contaminated air stream from the moisture separator using carbon adsorption, and treating water from the moisture separator in an on-site ultraviolet-hydrogen peroxide treatment plant. The ROD also specified the following cleanup levels for the treated soil:

- 2-Butanone: 1.2 ppm;
- Ethylbenzene: 6 ppm;
- Total xylenes: 23 ppm; and
- Tetrachloroethene: 0.2 ppm.

These cleanup levels were developed based on the results of a public health evaluation (PHE) performed as part of the OUFS and correspond to risk reductions of 92, 99, 97, and 98 percent for 2-butanone, tetrachloroethene, ethylbenzene, and total xylenes, respectively [1].

In addition, the ROD specified that the cleanup levels must be achieved within six months of system operation as verified by confirmatory sampling of soil in the Tank 2 Operable Unit [1].

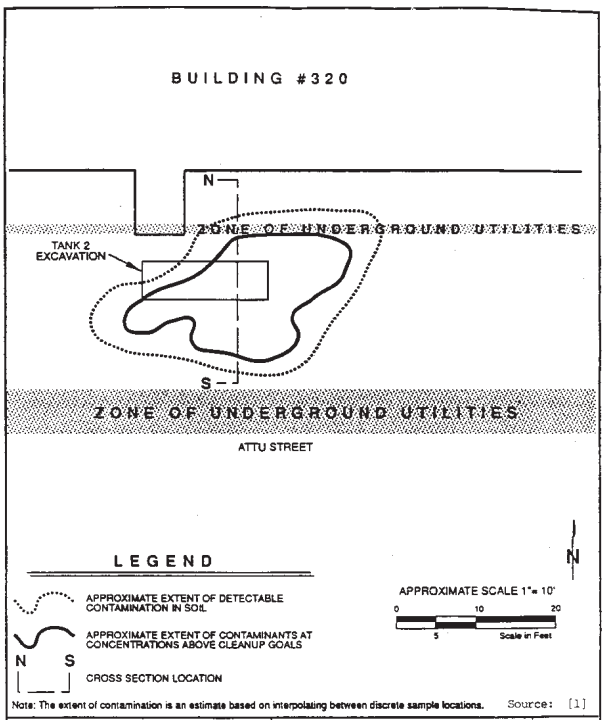

Figure 3. Soil Contamination-Plan View [1]

SITE INFORMATION (CONT.)

Background (cont.)

Remedy Selection: The ROD identified eight alternatives as remedial alternatives considered for the Tank 2 Operable Unit:

- No action;
- SVE with air emission control by either carbon adsorption, vapor recovery, or thermal vapor treatment, and on-site water treatment;
- SVE with air emission control by either carbon adsorption, vapor recovery, or thermal vapor treatment, and off-site water treatment;
- Excavation, soil washing, activated carbon vapor treatment, off-site liquid treatment, and backfill;
- Excavation, incineration, and backfill;
- Excavation, low temperature desorption, air emission control by gas-phase carbon adsorption or incineration, on-site water treatment, and backfill;
- Excavation, low temperature desorption, air emission control by gas-phase carbon adsorption or incineration, off-site water treatment, and backfill; and
- Excavation, surface aerobic biodegradation, and backfill.

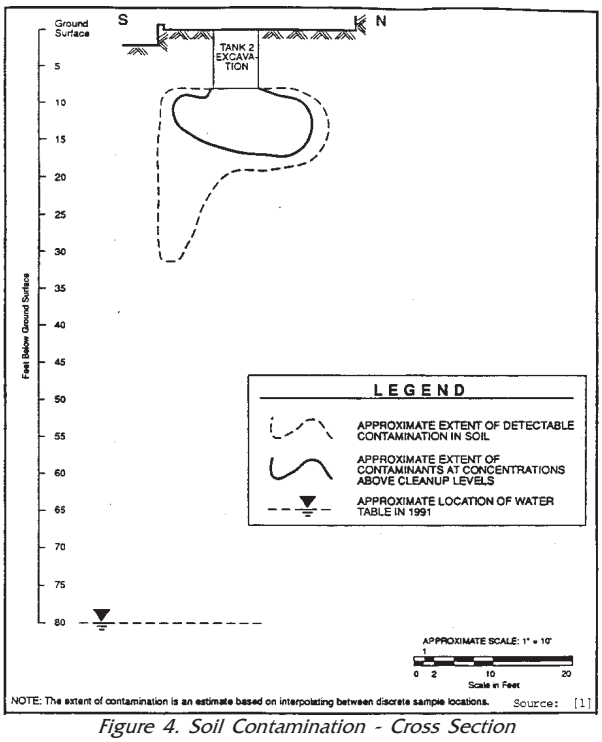

Figure 4. Soil Contamination - Cross Section

The ROD identified SVE, air emission control by carbon adsorption, and on-site water treatment as the selected remedy for the Tank 2 Operable Unit. This remedy was selected because it was the most cost effective of the alternatives considered.

Site Logistics/Contacts

Site Management: U.S. Army - Lead
Oversight: EPA

Remedial Project Manager:
Marlin Mezquita
U.S. EPA Region 9
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-2393

U.S. Army Facility Project Manager:
Dan Obern *(primary contact for this application)*
Sacramento Army Depot
8350 Fruitridge Road
Sacramento, CA 95813-5052
(916) 388-2489

U.S. Army Corps of Engineers Project Manager:
George Siller
U.S. ACE, Sacramento District
1325 J Street
Sacramento, CA 95814-2922

Treatment Vendor:
James A. Perkins
Terra Vac, Inc.
14798 Wicks Blvd.
San Leandro, CA 94577
(510) 351-8900

MATRIX DESCRIPTION

Matrix Identification

Type of Matrix Processed Through the Treatment System: Soil (in situ)

Contaminant Characterization

Primary Contaminant Groups: Volatile organic compounds (VOCs)

During the RI, samples were collected from 15 soil borings in the Tank 2 Operable Unit and analyzed for VOCs, polynuclear aromatic hydrocarbons, and pesticides. The primary constituents of concern were 2-Butanone, ethylbenzene, tetrachloroethene, and xylenes. As shown in Table 1, ethylbenzene and xylene were detected in 13.3 and 21.0 percent of the samples analyzed, respectively, and at maximum concentrations of 2,100 and 11,000 mg/kg, respectively. The constituents 2-butanone and tetrachloroethene were detected in 4.8 and 5.7 percent of the samples analyzed, respectively, and at maximum concentrations of 150 and 390 mg/kg, respectively. [1]

Table 1. Subsurface Soil Contamination Levels in the Tank 2 Operable Unit [1]

Constituent	Total Number of Samples Analyzed	Percent of Times Detected	Range of Detected Concentrations (mg/kg)
2-Butanone	105	4.8	0.011 to 150
Ethylbenzene	105	13.3	0.006 to 2,100
Tetrachloroethene	105	5.7	0.006 to 390
Xylenes	105	21.0	0.005 to 11,000

Matrix Characteristics Affecting Treatment Cost or Performance

The major matrix characteristics affecting cost or performance for this technology and their measured values are listed in Table 2. [5]

The following additional matrix characteristics were measured [5]:

Unit weight, dry: ..... 94.0 to 98.1 lbs/ft^3
pH: ..... 7.0 to 7.8
Nitrate as N: ..... 2.7 to 3.8 mg/kg
Kjeldahl nitrogen as N: ..... 15.2 to 91.4 mg/kg
Cation exchange capacity: ..... 20.2 to 118 milliequivalents per 100 grams (as Na)
Chemical oxygen demand: ..... 500 to 5,750 mg/kg

Table 2. Matrix Characteristics [5, 6, 7]

Parameter	Value	Measurement Method
Soil Classification	Silt	USCS Field Determination
Clay Content	<30%	Laser Particle Analysis
Particle Size Distribution	2.5-10 Φ	Laser Particle Analysis
Moisture Content	25.6 to 26.5%	Dean-Stark
Air Permeability	1.7×10^{-7} to 6.2×10^{-5} cm/sec	API PR 40 @ 25psi
Porosity	44.3 - 45.8%	—
Total Organic Carbon	0.011 to 0.44%	Not available
Nonaqueous Phase Liquids	Not Detected	Dean-Stark

MATRIX DESCRIPTION (CONT.)

Site Geology/Stratigraphy

The soil underlying the Tank 2 Operable Unit generally consists of soil and clay with imbedded units of sand and silty sand. Figures 5 and 6 show the A-A' and B-B' geologic cross-sections for the Tank 2 Operable Unit, respectively. These cross-sections were prepared based on the logs for 15 soil borings completed in the Tank 2 Operable Unit during the RI. Figure 7 shows the locations of these borings within the Tank 2 Operable Unit. Boring logs for borings TT-1, TT-3, TT-5, TT-10, TT-11, TT-12, and TT-13 indicate that:

- A 6-9 feet unit of medium to very dense, fine grained sand is present 12 to 21 feet below the ground surface; and
- The soil 20 to 22 feet below the ground surface consists of a laterally continuous unit of very stiff to hard clay-silt/clay, which is white to gray-white in color.

The logs for borings TT-1, TT-2, TT-5, and TT-8 indicate that a unit of very stiff to hard clayey-silt is present 26 to 29 feet below the ground surface. This unit contains trace amounts of fine sand and does not appear to be laterally continuous since it is not present in borings TT-3, TT-6, TT-7, and TT-10 through TT-15. [5]

The depth to groundwater beneath the Tank 2 Operable Unit is approximately 80 feet below the ground surface. [5]

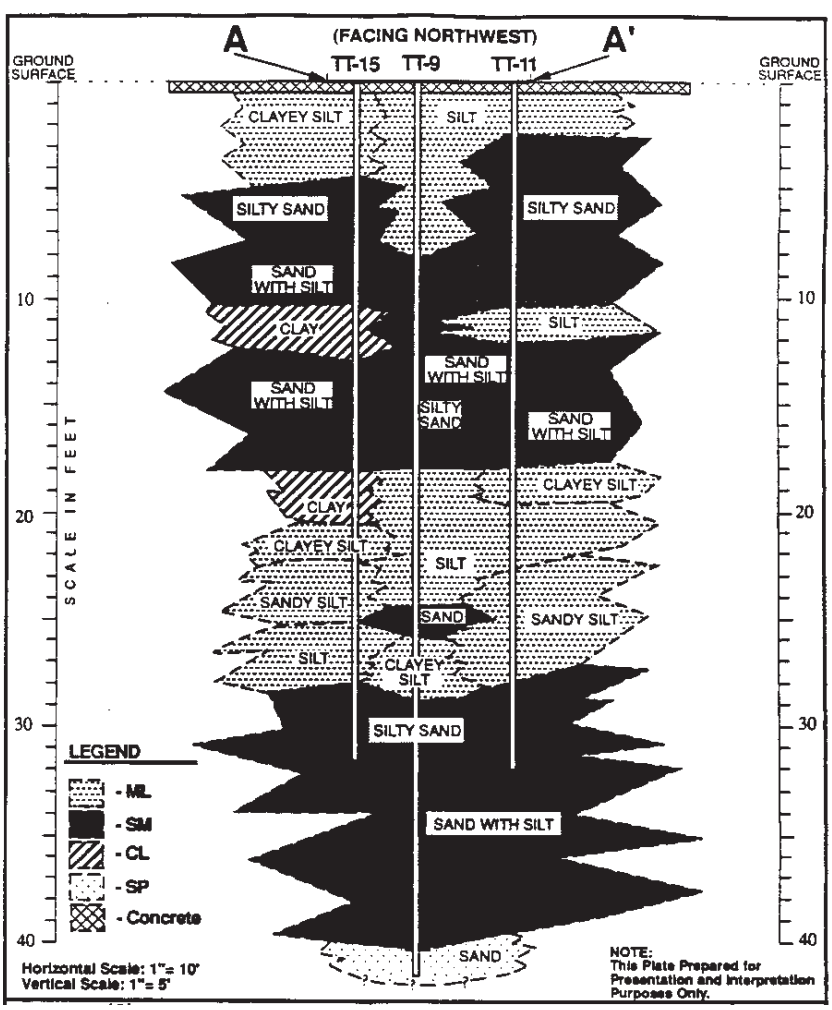

Figure 5. Cross Section A-A' [5]

MATRIX DESCRIPTION (CONT.)

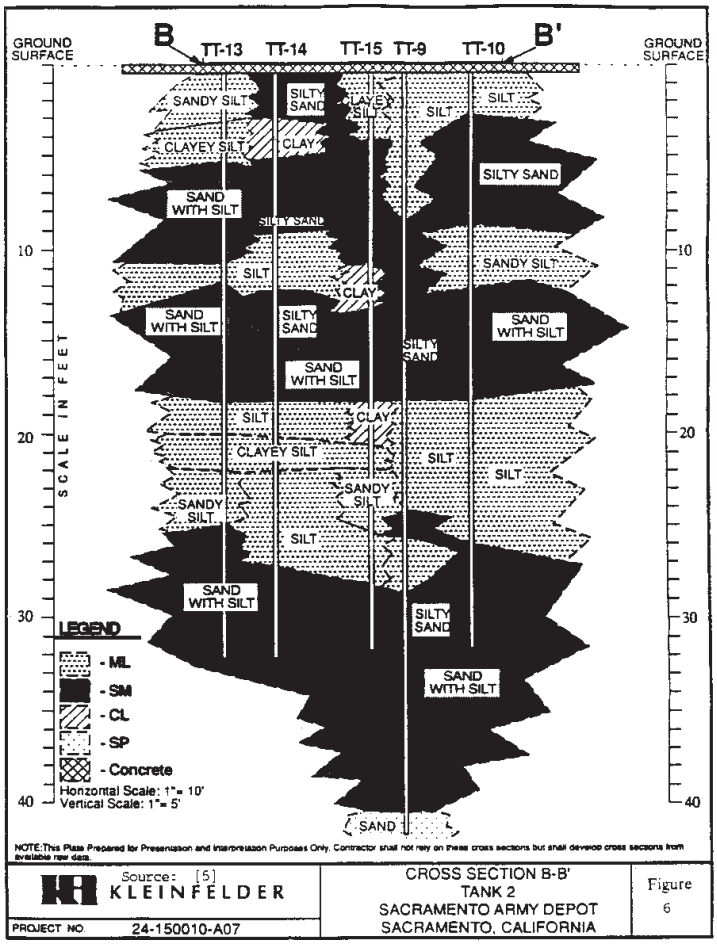

Figure 6. Cross Section B-B' [5]

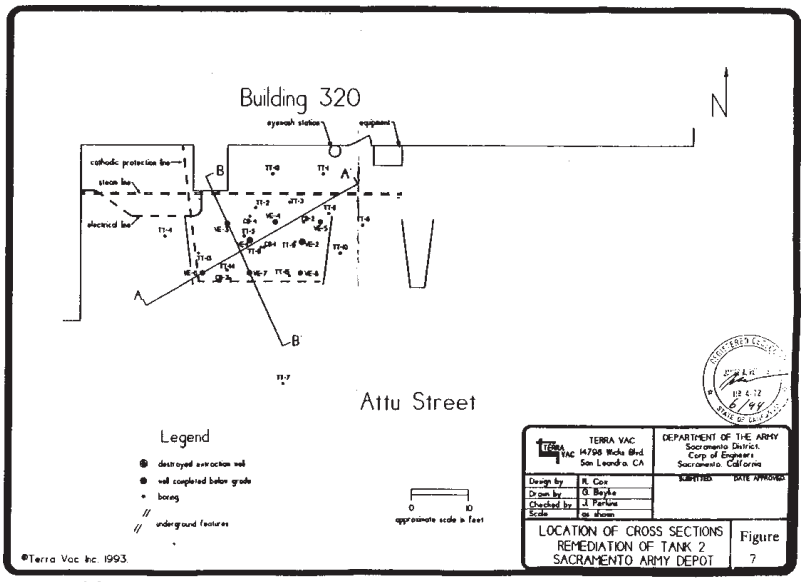

Figure 7. Cross Section Locations [5]

TREATMENT SYSTEM DESCRIPTION

Primary Treatment Technology Type

Soil vapor extraction

Supplemental Treatment Technology Types

Post-treatment of vapors: moisture separator, carbon adsorption

Soil Vapor Extraction System Description and Operation

System Description

The SVE system used at the Tank 2 Operable Unit consisted of eight vacuum extraction wells (VE-1 through VE-8), a positive displacement blower, a vapor-liquid separator, and primary and secondary carbon filters, as shown on Figure 8. This system was designed by the vendor to remove approximately 1,650 pounds of ethylbenzene and xylene (based on RI results) within the six month period specified in the ROD. Wells VE-1 and VE-2 were installed and operated during a treatability study and were used for the full-scale treatment application. These wells were installed to a depth of 18 feet below the ground surface. Wells VE-3 through VE-8 were installed during July 1992, just prior to system start-up on August 6, 1992, at depths ranging from 15 to 28 feet below the ground surface. Appendix B contains the boring logs for these extraction wells showing the exact completion depth and presenting information on the specific materials of construction for each well. [2]

Eight vacuum extraction wells were required at the relatively small site due to the low permeability of site soils and the schedule. The ROD specified that the cleanup had to be completed within 6 months after initiation. The large number of wells were required to meet the schedule. [9]

The soil cuttings generated when wells VE-3 through VE-8 were drilled were placed in a lined box. The box was piped into the SVE system so that the cuttings could be treated. Wells VE-1 through VE-8 and the box containing the soil cuttings were connected to a 30-horsepower positive displacement blower by above-ground distribution piping. [2]

Vapors extracted using the vacuum extraction wells were treated using a vapor-liquid separator and carbon adsorption units. The vapor first passed through the vapor-liquid separator where entrained water was separated from the vapor and stored for future treatment in the ultraviolet-hydrogen peroxide treatment plant operated at SAAD. A total of 70 gallons of water were generated during the treatment application. The vapor from the vapor-liquid separator then passed through 1,000-pound primary and secondary carbon units that were placed in series. A total of 33,000 pounds of spent carbon were generated during the treatment application. Treated vapor from the secondary carbon unit was vented to the atmosphere. [2]

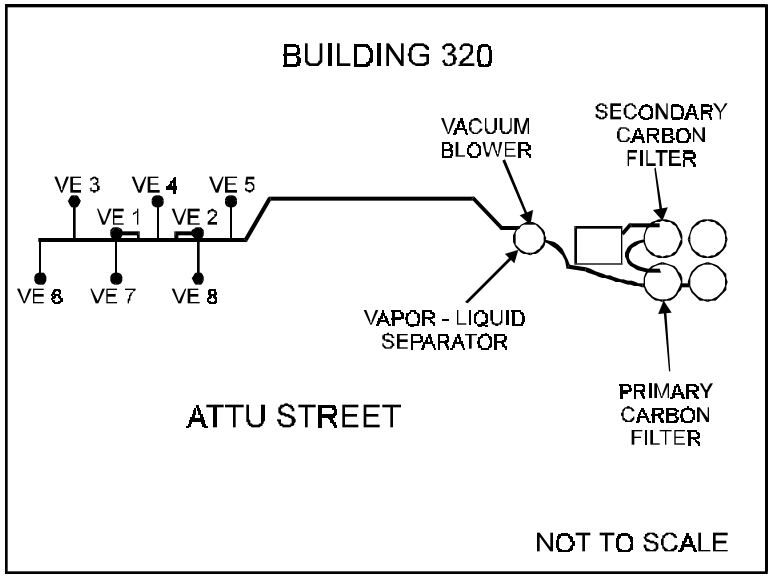

Figure 8. SVE Plot Plan [2]

TREATMENT SYSTEM DESCRIPTION (CONT.)

Soil Vapor Extraction Treatment System Description and Operation (cont.)

System Operation [2,7]

The vacuum extraction wells were installed and the SVE system was assembled at the site in July 1992. The SVE system was operated at the Tank 2 Operable Unit from August 6, 1992 until January 21, 1992 for a total of 102 days. Confirmatory samples were collected on March 22 and 23, 1993. The results of these samples indicated that the cleanup levels had been achieved. The SVE equipment was demobilized and the site restored between March and April 1993. Site restoration activities included off-site disposal of the treated soil from well borings, and destroying wells VE-1, VE-2, VE-4, VE-5, VE-6, and VE-8. Wells VE-3 and VE-7 were completed below grade and, therefore, were left open.

On January 21, 1993, extraction was stopped because the rate of extraction of target compounds had been decreased to less than 0.01 pounds per day. To determine the residual amounts of target contaminants, the system was shut down for five days. On January 26, the system was started up again and the rate of extraction of target contaminants was measured. The target contaminants were still being extracted at less than 0.01 pounds per day. Since the extraction rates of target contaminants remained low, the system was shut down.

Extraction of Freon [2,7]

Shortly after system start-up, the treatment vendor discovered that the SVE system was extracting significant amounts of Freon 113, in addition to the contaminants of concern. Approximately 50 pounds per day of Freon 113 were being extracted from the wells. Vapor concentrations data indicated that most of the Freon 113 was being extracted from beneath Building 320, located at the North end of the site. The unexpected extraction of Freon 113 caused an increase in the carbon utilization rate above what the vendor had estimated prior to operating the system. In response, the vendor performed several activities to decrease the amount of Freon 113 extracted from the wells:

- Wells VE-3, VE-4, and VE-5, which were adjacent to Building 320, were taken off line. By venting wells VE-3, VE-4, and VE-5 to the atmosphere, a passive pneumatic barrier was created, resulting in significant reduction of Freon 113 extraction from the other 5 wells.
- Since extraction rates of ethylbenzene and xylenes from wells VE-4 and VE-5 had been high before they were taken off line, an attempt was made to bring these wells back on line. An ejection test was performed on November 5, 1992. Air was injected into wells VE-3, VE-4, and VE-5 and any changes in the amount of Freon 113 extracted from the other wells were recorded. The rationale of the test was that an active pneumatic barrier could be created which would reduce the extraction of Freon from beneath Building 320. The results of the injection test showed that extraction could be successfully resumed at wells VE-3, VE-4, and VE-5 if an active pneumatic barrier was established between these wells and Building 320. The installation of 7 air injection probes was proposed. However, during installation the probes were obstructed at 5 - 7 feet below grade and the probes were abandoned.

On December 16, 1992, wells VE-3, VE-4, and VE-5 were put back on line to determine residual Freon levels. The amount of extracted Freon had dropped to between 10 and 18 pounds per day.

TREATMENT SYSTEM DESCRIPTION (CONT.)

Operating Parameters Affecting Treatment Cost or Performance

The major operating parameters affecting cost or performance for this technology and their values measured during this treatment application are listed in Table 3. Information on daily air flow rates is presented in Appendix B. [2]

Table 3. Operating Parameters [2]

Parameter	Value	Measurement Method
Air Flow Rate	16 to 365 scfm	Not available
Vacuum	Not available	—

Timeline

The timeline for this application is presented in Table 4.

Table 4. Timeline [2]

Start Date	End Date	Activity
7/22/87	—	SAAD added to National Priorities List
12/9/91	—	ROD signed.
7/13/92	8/3/92	Vacuum extraction wells installed and SVE system assembled.
8/6/92	10/29/92	SVE system operated.
10/29/92	11/13/92	System shut down so that air injection test could be performed.
11/13/92	11/25/92	SVE system operated.
11/25/92	12/14/92	SVE system shut down to attempt installation of vent probes.
12/14/92	12/25/92	SVE system operated with wells VE-1, VE-2, VE-4, and VE-5 on line.
12/25/92	1/4/93	SVE system shut down due to equipment failure.
1/4/93	1/21/93	SVE system operated.
1/21/93	1/25/93	SVE system shut down to prepare for start-up spike test.
1/26/93	—	Start-up spike test performed. No spike detected.
1/25/93	3/22/93	Drilling plan for confirmatory soil borings reviewed and approved.
3/22/93	3/23/93	Confirmatory soil samples collected.
3/23/93	4/22/93	Equipment demobilized and site restored.

TREATMENT SYSTEM PERFORMANCE

Cleanup Levels

The 1991 ROD specified the following cleanup levels for the treated soil at the Tank 2 Operable Unit [1]:

- 2-Butanone: 1.2 ppm;
- Ethylbenzene: 6 ppm;
- Tetrachloroethene: 0.2 ppm; and
- Total xylenes: 23 ppm.

The ROD specified that these cleanup levels were to be achieved by removing VOCs using an SVE system with a moisture separator, activated carbon unit, and ultraviolet-hydrogen peroxide water treatment plant. Additionally, the ROD specified that the cleanup levels were to be achieved within approximately six months of system operation.

The cleanup levels for the four constituents were developed based on the results of a public health evaluation performed as part of the OUFS. The cleanup levels for 2-butanone, ethylbenzene, tetrachloroethene, and xylenes result in estimated 92, 97, 99, and 98 percent reductions in human health risks, respectively.

Ambient air standards were based on a 10^{-6} health risk criterion. [11]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Treatment Performance Data [2, 9]

Confirmatory soil sampling was conducted at the Tank 2 Operable Unit on March 22 and 23, 1993 to assess whether the cleanup levels specified in the ROD had been achieved. Four soil borings were completed in the Tank 2 area and are referred to as confirmatory borings (CB). Figure 7 shows the locations of CB-1 through CB-4 in the Tank 2 Operable Unit. Three samples were collected from each boring; one from an interval 9-10.5 feet below the ground surface, one from 12-13.5 feet below the ground surface, and one 15-16 feet below the ground surface. These samples were analyzed for 2-butanone, ethylbenzene, tetrachloroethene, and xylenes using EPA Method 8240. The samples were also tested for Freon 113.

2-Butanone was detected in samples collected from borings CB-1, CB-2, and CB-4 at concentrations of 0.0038, 0.003, and 0.0051 mg/kg, respectively. Ethylbenzene was detected in one sample collected from CB-4 at a concentration of 0.021 mg/kg. Total xylenes were detected in two samples collected from CB-4 at concentrations of 0.018 and 0.140 mg/kg. Tetrachloroethene and Freon 113 were not detected in any of the samples collected from borings CB-1 through CB-4. The results of these samples are presented in Table 5.

Additionally, vapor samples were collected throughout the operation of the SVE system at the Tank 2 Operable Unit and measured for VOCs using direct injection into a gas chromatograph. The results for these samples, along with air flow measurements collected during system operation, were used to estimate the mass of VOCs removed and the extraction rates for VOCs.

Figure 9 shows the mass of total VOCs, Freon 113, and non-Freon VOCs removed during system operation. Approximately 2,300 pounds of total VOCs, 1,800 pounds of Freon 113, and 500 pounds of non-Freon VOCs were extracted during this application. Figure 10 shows the extraction rates of total VOCs, Freon 113, and non-Freon VOCs during system operation. The extraction rates ranged from approximately 5 to 120 pounds per day of total VOCs, 5 to 80 pounds per day of Freon 113, and 0 to 110 pounds per day of non-Freon VOCs during this application. The data used to generate these plots is contained in Appendix B.

Ambient air sampling was performed during intrusive work, such as construction and drilling, and also periodically during routine operation. The ambient air standards were met, as no emissions were detected by the monitoring devices.

Performance Data Assessment

As shown in Table 5, the cleanup levels specified in the ROD were achieved for the four specified constituents within the required six months of system operation. 2-butanone, ethylbenzene, tetrachloroethene, and total xylenes were not detected in 82 percent of the confirmatory soil samples.

The highest concentration detected in these samples was total xylenes at 0.140 ppm in the sample collected from the 12-13.5 feet depth interval at CB-4.

In addition, Freon 113 was not detected in any of the samples. As shown on Figure 9, Freon 113 accounted for 1,800 of the estimated 2,300 pounds of VOCs removed during this application. As shown in Figure 10, the extraction rate for non-Freon VOCs decreased to nearly zero after approximately 78 days of operation and remained at this level until the system was shut down after 102 days. The extraction rate for Freon 113, however, remained near 15 lbs/day during this period.

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (cont.)

Table 5. Results for Confirmatory Soil Borings [2, 7]

Constituent	Boring No.	CB-1			CB-2			CB-3			CB-4		
	Interval (ft)	9-10.5	12-13.5	15-16	9-10.5	12-13.5	15-16	9-10.5	12-13.5	15-16	9-10.5	12-13.5	15-16
	Cleanup Level (mg/kg)	(mg/kg)											
2-Butanone	1.2	0.0038	ND (0.005)	ND (0.005)	0.003	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	0.0051
Ethylbenzene	6	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	ND (0.005)	0.021	ND (0.005)
Tetrachloroethene	0.2	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)	ND (0.010)
Total Xylenes	23	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	ND (0.015)	0.018	0.14	ND (0.015)
Freon 113	NA	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)

ND = Not detected. Number in parenthesis is the reported detection limit.
NA = Not Applicable

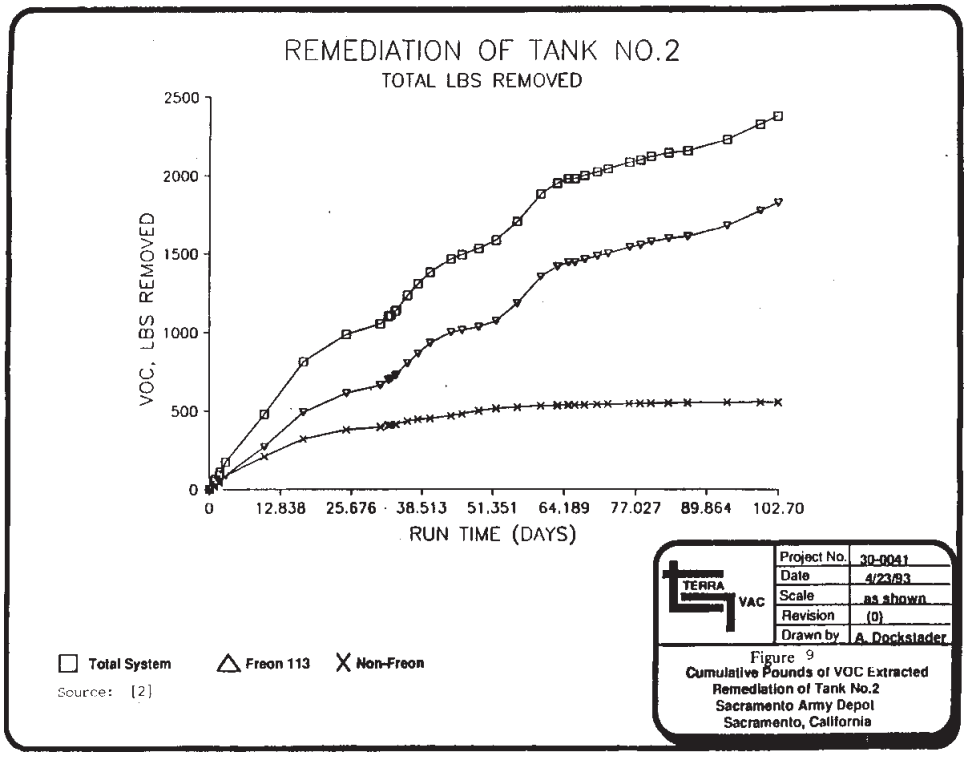

Figure 9. Cumulative Pounds of VOC Extracted [2]

TREATMENT SYSTEM PERFORMANCE (CONT.)

Performance Data Assessment (cont.)

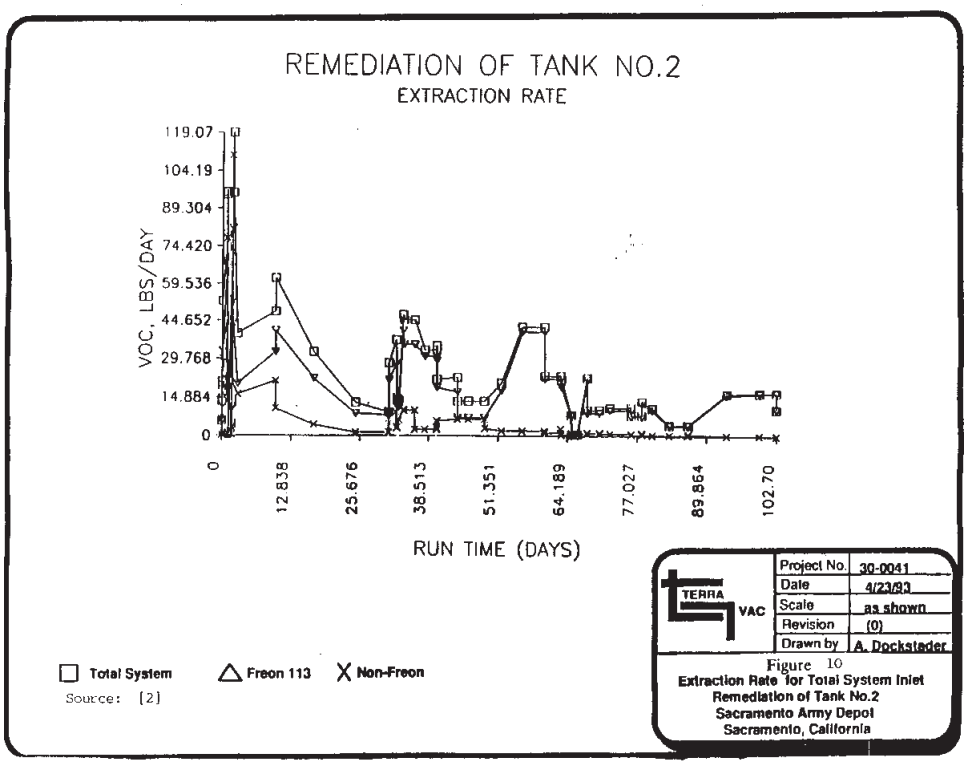

Figure 10. VOC Extraction Rates [2]

Performance Data Completeness

The soil boring data allow for comparison of performance of the SVE system with respect to the cleanup levels specified in the ROD. Additionally, the concentrations of VOCs and air flow were measured at the SVE system inlet for estimating the cumulative pounds of VOCs removed and extraction rates over the course of system operation.

Performance Data Quality

Ten percent of the samples collected during this application, including the soil boring samples, were split and analyzed by both the contractors and the U.S. Army Corps of Engineers. No analytical concerns were reported by the Army. Soil boring samples were analyzed in accordance with EPA Method 8240 including accepted criteria for use of the method.

TREATMENT SYSTEM COST

Procurement Process

The U.S. Army was responsible for site management during this treatment application. The U.S. Army, through the Corps of Engineers (USACE), retained Terra Vac to design, install, and operate the SVE system at the site.

Kleinfelder, Inc., provided support to the Army at SAAD under a basewide contract. Kleinfelder was responsible for completing a computer modelling treatability study of an SVE system, and collection of duplicate samples during the remediation. This model was used as a treatability study. The model predicted that an SVE system with 4 extraction wells and a volumetric flow rate of 500 cfm would reduce the concentrations of ethylbenzene and total xylenes to non-detectable levels within 6 months. [10]

Treatment System Cost

Terra Vac reported a total cost of $556,000 for this application, excluding costs for construction management and Title II services.

The original contract between USACE and Terra Vac for remediation of the site was for $400,549. However, the actual cost of remediation was greater. The discrepancy between the contractual and actual costs was due primarily to the unexpected extraction of large amounts of Freon, and the corresponding increase in amount of carbon required for this application. The cost of extra carbon and its disposal are included in the "operation" cost in Table 6. [7, 8]

Table 6 presents the costs reported by the vendor for the soil vapor extraction application at the Sacramento Army Depot Superfund Site. In order to standardize reporting of costs across projects, costs are shown in Table 6 according to the format for an interagency Work Breakdown Structure (WBS). The WBS specifies 9 before-treatment cost elements, 5 after-treatment cost elements, and 12 cost elements that provide a detailed breakdown of costs directly associated with treatment. Table 6 presents the cost elements exactly as they appear in the WBS.

As shown on Table 6, over 60% of the costs are for operation of the SVE system, including off-gas treatment using carbon (the vendor included sampling and analysis costs under operation). To estimate a cost per cubic yard of soil and per pound of contaminant treated, the costs for operation were disaggregated into a cost for treatment of Freon and non-Freon contaminants. This was done to assess the effect of the unexpectedly large amount of Freon on the calculated costs. Operating costs were assumed to be equivalent on a per unit basis for treatment of Freon and non-Freon contaminants. This approach shows that about $266,000 of the operating costs were for treatment of Freon, and $74,000 for treatment of non-Freon contaminants. Total costs for treatment of non-Freon contaminants, therefore, were $290,000, corresponding to $450 per cubic yard of soil treated and $580 per pound of non-Freon contaminant removed. The number of cubic yards of soil treated at SAAD is an estimate provided by the vendor; the actual amount of soil treated is not available at this time for comparison with the estimate.

Table 6. Treatment Cost Elements [3]

Cost Elements (Directly Associated with Treatment)	Acutal Cost (dollars)
Mobilization/Set Up	131,813
Startup/Testing/Permits	18,500
Operation (Short Term - Up to 3 Years)	339,694
Demobilization	65,967
TOTAL TREATMENT COST	**556,000**

The vendor indicated that there were no costs in this application for the following elements in the WBS: Solids Preparation and Handling, Liquid Preparation and Handling, Vapor/Gas Preparation and Handling, Pads/Foundations/Spill Control, Training, Operation (Long Term - Over 3 Years), Cost of Ownership, Dismantling, Mobilization and Preparatory Work, Site Work, Surface Water Collection and Control, Groundwater Collection and Control, Air Pollution/Gas Collection and Control, Solids Collection and Containment, Liquids/Sediments/Sludges Collection and Containment, Drums/Tanks/Structures/Miscellaneous Demolition and Removal, Decontamination and Decommissioning, Disposal (Other Than Commercial), Disposal (Commercial), and Site Restoration.

TREATMENT SYSTEM COST (CONT.)

Cost Data Quality

Total cost information was provided by the Army's contractor for this project. Limited information on the specific cost elements included in the total cost figure were provided by the vendor.

Vendor Input

The vendor specified that the main factors driving the cost of SVE are soil permeabilities and the types of contaminants at the site and the schedule for final cleanup. [9]

OBSERVATIONS AND LESSONS LEARNED

Cost Observations and Lessons Learned

- The total cost for the SVE treatment application at the SAAD Tank 2 Operable Unit, excluding construction management and Title II services, was $556,000.
- The total cost was adjusted to show a calculated cost for treatment of soil without including the costs attributed to the Freon. The adjusted cost was $290,000, which corresponds to $450/cubic yard of soil treated.
- Several activities (air injection test, vent probe installation) performed due to the unexpected extraction of Freon 113 and the additional carbon required were not anticipated in the original scope of work for this treatment application; therefore, the total cost for the treatment application was about 40% greater than the cost originally estimated by the vendor and contracted by USACE.

Performance Observations and Lessons Learned

- The cleanup levels for soil established in the ROD were achieved after operating the SVE system for approximately 102 days. Thus, the requirement to achieve the cleanup levels within six months was also achieved.
- 2-Butanone, ethylbenzene, tetrachloroethene, and total xylenes were not detected in 82 percent of the confirmatory soil boring samples.
- Freon 113 was not detected in the confirmatory soil boring samples.
- Most of the non-Freon VOCs were removed after approximately 78 days of operation.

Other Observations and Lessons Learned

- The majority of the estimated 2,300 pounds of VOCs removed during this application consisted of Freon 113 (approximately 1,800 pounds removed).
- The presence of Freon 113 was not identified during the RI prior to system operation and, according to the vendor, was believed to be migrating from an off-site source.
- The computer model treatability study predicted that an SVE system with 4 extraction wells and a volumetric flow rate of 500 cfm would reduce the concentrations of ethylbenzene and total xylenes to non-detectable levels within 6 months.

REFERENCES

1. *Superfund Record of Decision*, Sacramento Army Depot (Operable Unit 3), California, U.S. EPA, Office of Emergency and Remedial Response, EPA/ROD/R09-02/077, December 1991.
2. Final Report; Remediation of Tank 2; Sacramento Army Depot; Sacramento, California; November 1991 - April 1993; Terra Vac Corporation, San Leandro, California; includes Analytical Summary, Remediation of Tank 2 (Volumes I-III) Vacuum Extraction Soil Remediation; undated.
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4. Tank 2 Operable Unit Technical Memoranda on Field Activities; Appendix A-1, Part 1 of 2 of the Remedial Investigation Report; Sacramento Army Depot; Kleinfelder, Inc., October 25, 1991.
5. Tank 2 Operable Unit Feasibility Study, (Volumes I-III), Sacramento Army Depot, Sacramento, California; Kleinfelder, Inc.; August 2, 1991.
6. Perkins, J., G. Siller, C. Steele, and D. Obern. "Remediation of Tank No. 2 Sacramento Army Depot Sacramento, California" In: Proceedings of HAZMACON '94. Hazardous Materials Management Conference and Exhibition, San Jose, California, 1994, pp. 428-440.
7. Letter from James A. Perkins of Terra Vac, November 28, 1994.
8. Telecon regarding conversation with James A. Perkins of Terra Vac, January 6, 1995.
9. Telecon regarding conversation with James A. Perkins of Terra Vac, February 2, 1995.
10. Treatability Study report, Tank 2 Operable Unit, Sacramento Army Depot, Kleinfelder, Inc. February 25, 1991.
11. Memo from Pamela Wee, Kleinfelder, Inc., to Linda Fiedler, EPA/TIO. February 8, 1995.

Analysis Preparation

This case study was prepared for the U.S. Environmental Protection Agency's Office of Solid Waste and Emergency Response, Technology Innovation Office. Assistance was provided by Radian Corporation under EPA Contract No. 68-W3-0001.

APPENDIX A—OPERATING SUMMARY

Operating Summary
Remediation of Tank No. 2
Sacramento Army Depot [2]

Sample Time			Operating Summary					
Date	Hrs	Min	Sample Number*	Run Time (Days)	Flow Rate (SCFM)	Total (mg/L)	Total Rate (#/Day)	Cum VOC (lbs)
05-Aug	14	20	777	0.00	0.00	0.00		0
05-Aug	14	44	1	0.02	23.00	2.74	6	0
05-Aug	15	20	2	0.04	20.00	3.30	6	0
05-Aug	15	30	3	0.05	49.00	2.95	13	0
05-Aug	15	55	4	0.07	49.00	4.73	21	1
05-Aug	16	45	5	0.10	49.00	4.36	19	1
05-Aug	17	10	6	0.12	97.00	6.05	52	2
06-Aug	10	10	10	0.83	97.00	8.52	74	47
06-Aug	11	0	12	0.86	46.00	18.91	79	49
06-Aug	11	25	15	0.88	46.00	22.68	95	51
06-Aug	12	0	16	0.90	46.00	22.93	96	53
06-Aug	14	45	18	1.02	43.00	10.42	40	61
06-Aug	15	0	19	1.03	43.00	9.86	38	61
06-Aug	15	30	20	1.05	43.00	7.15	27	62
06-Aug	15	35	21	1.05	46.00	16.61	68	62
06-Aug	16	35	23	1.09	46.00	15.00	62	65
06-Aug	16	40	24	1.10	43.00	9.79	38	65
06-Aug	17	20	25	1.13	43.00	11.51	44	66
06-Aug	17	45	26	1.14	43.00	11.93	46	67
06-Aug	17	50	27	1.15	16.00	0.32	0	67
06-Aug	18	50	28	1.19	16.00	0.61	1	67
07-Aug	10	15	33	1.83	84.00	9.31	70	90
07-Aug	10	55	36	1.86	32.00	1.56	4	91
07-Aug	11	25	37	1.88	28.00	4.99	12	91
07-Aug	11	55	38	1.90	28.00	5.68	14	91
07-Aug	12	15	999	1.91	0.00	5.68	14	91
10-Aug	12	20	777	1.91	0.00	5.68	14	91
10-Aug	13	5	39	1.94	187.00	11.41	192	95
10-Aug	15	10	40	2.03	111.00	12.00	119	108
10-Aug	16	15	47	2.08	111.00	9.61	95	113
11-Aug	13	35	48	2.97	121.00	3.65	40	173
18-Aug	13	30	69	9.96	71.00	7.59	48	480
18-Aug	14	5	73	9.99	129.00	5.34	62	482
25-Aug	14	0	77	16.98	129.00	2.79	32	811
02-Sep	9	5	78	24.78	130.00	1.10	13	988
08-Sep	14	1	87	30.98	166.00	0.62	9	1056
08-Sep	15	30	999	31.05	0.00	0.62	9	1056

*777 = Start-up, 888 = No sample taken, 999 = Shut-down

APPENDIX A—OPERATING SUMMARY (CONT.)

Operating Summary (Continued)
Remediation of Tank No. 2
Sacramento Army Depot

Sample Time			Operating Summary					
Date	Hrs	Min	Sample Number*	Run Time (Days)	Flow Rate (SCFM)	Total (mg/L)	Total Rate (#/Day)	Cum VOC (lbs)
10-Sep	8	0	777	31.05	0.00	0.62	9	1056
10-Sep	8	45	92	31.08	136.00	2.30	28	1057
11-Sep	16	47	96	32.41	136.00	3.03	37	1100
11-Sep	18	30	999	32.48	0.00	3.03	37	1103
14-Sep	14	45	777	32.48	0.00	3.03	37	1103
14-Sep	17	15	102	32.59	193.00	0.84	15	1106
14-Sep	17	45	999	32.61	0.00	0.84	15	1106
15-Sep	7	45	777	32.61	0.00	0.84	15	1106
15-Sep	8	57	103	32.66	193.00	0.80	14	1107
15-Sep	16	30	888	32.97	193.00	0.80	14	1111
16-Sep	10	30	114	33.72	232.00	2.26	47	1134
16-Sep	15	45	116	33.94	223.00	2.25	45	1144
18-Sep	15	30	999	35.93	0.00	2.25	45	1234
21-Sep	14	5	777	35.93	0.00	2.25	45	1234
21-Sep	14	15	888	35.94	243.00	2.25	45	1234
23-Sep	11	25	120	37.82	214.00	1.72	33	1307
25-Sep	16	0	999	40.01	0.00	1.72	33	1380
28-Sep	15	15	777	40.01	0.00	1.72	33	1380
28-Sep	15	20	128	40.01	232.00	1.67	35	1380
28-Sep	15	50	130	40.03	225.00	1.08	22	1380
02-Oct	11	45	135	43.86	263.00	0.96	23	1466
02-Oct	12	35	136	43.90	311.00	0.48	13	1466
04-Oct	12	0	999	45.88	0.00	0.48	13	1493
05-Oct	14	40	777	45.88	0.00	0.48	13	1493
05-Oct	14	45	888	45.88	311.00	0.48	13	1493
08-Oct	14	0	888	48.85	305.00	0.48	13	1532
08-Oct	14	45	999	48.88	0.00	0.48	13	1533
12-Oct	13	0	777	48.88	0.00	0.48	13	1533
12-Oct	13	15	888	48.89	294.00	0.48	13	1533
15-Oct	15	15	145	51.97	294.00	0.78	21	1585
19-Oct	10	45	153	55.78	305.00	1.54	42	1705
23-Oct	14	45	999	59.95	0.00	1.54	42	1881
26-Oct	14	0	777	59.95	0.00	1.54	42	1881
26-Oct	14	45	156	59.98	324.00	0.80	23	1882
29-Oct	12	0	999	62.90	0.00	0.80	23	1949
03-Nov	12	0	777	62.90	0.00	0.80	23	1949
03-Nov	15	0	170	63.03	300.00	0.81	22	1952

*777 = Start-up, 888 = No sample taken, 999 = Shut-down

APPENDIX A—OPERATING SUMMARY (CONT.)

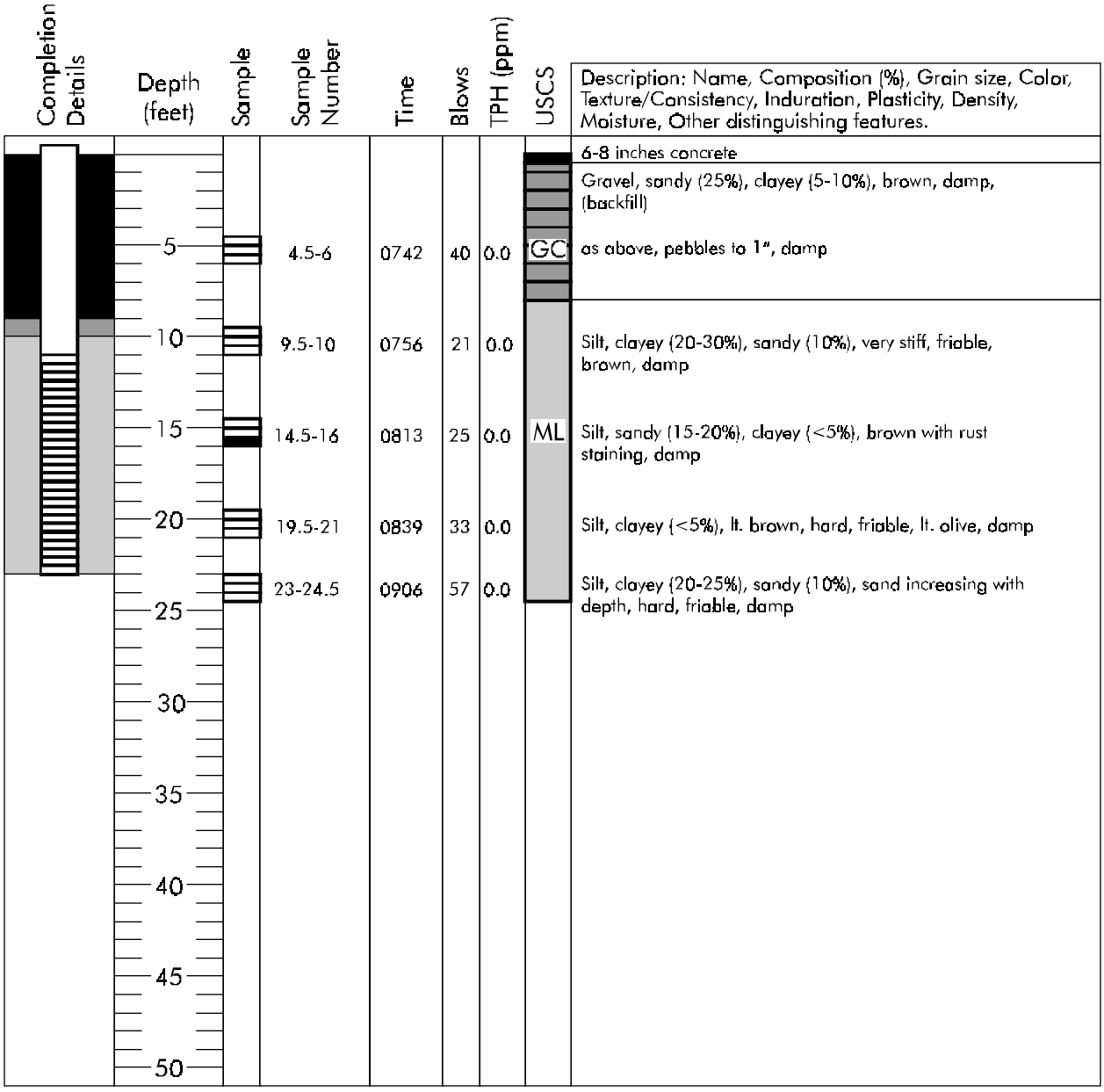
Operating Summary (Continued)
Remediation of Tank No. 2
Sacramento Army Depot

Sample Time			Operating Summary					
Date	Hrs	Min	Sample Number*	Run Time (Days)	Flow Rate (SCFM)	Total (mg/L)	Total Rate (#/Day)	Cum VOC (lbs)
05-Nov	11	0	177	64.86	251.00	0.36	8	1979
05-Nov	15	0	183	65.03	293.00	0.02	1	1980
06-Nov	16	0	999	66.07	0.00	0.02	1	1980
09-Nov	14	50	777	66.07	0.00	0.02	1	1980
11-Nov	8	15	184	67.80	203.00	1.23	22	2000
11-Nov	9	8	196	67.83	191.00	0.58	10	2001
13-Nov	15	30	999	70.10	0.00	0.58	10	2023
17-Nov	13	0	777	70.10	0.00	0.58	10	2023
19-Nov	12	0	199	72.06	170.00	0.71	11	2043
23-Nov	8	30	999	75.91	0.00	0.71	11	2085
23-Nov	13	0	777	75.91	0.00	0.71	11	2085
23-Nov	13	30	202	75.93	213.00	0.41	8	2085
25-Nov	12	0	999	77.87	0.00	0.41	8	2100
16-Dec	11	0	777	77.87	0.00	0.41	8	2100
16-Dec	11	50	211	77.90	280.00	0.52	13	2101
18-Dec	10	0	217	79.83	243.00	0.48	11	2124
21-Dec	12	48	218	82.94	350.00	0.13	4	2146
25-Dec	0	0	999	86.41	0.00	0.13	4	2160
05-Jan	9	30	777	86.41	0.00	0.13	4	2160
05-Jan	12	48	888	86.55	334.00	0.13	4	2161
12-Jan	12	48	231	93.55	365.00	0.50	16	2232
18-Jan	12	48	244	99.55	284.00	0.66	17	2331
21-Jan	15	30	999	102.66	0.00	0.66	17	2383
26-Jan	10	15	777	102.66	0.00	0.66	17	2383
26-Jan	10	35	255	102.67	274.00	0.42	10	2383
26-Jan	11	15	999	102.70	0.00	0.42	10	2383

*777 = Start-up, 888 = No sample taken, 999 = Shut-down

APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-3
Date Drilled: 7/17/92



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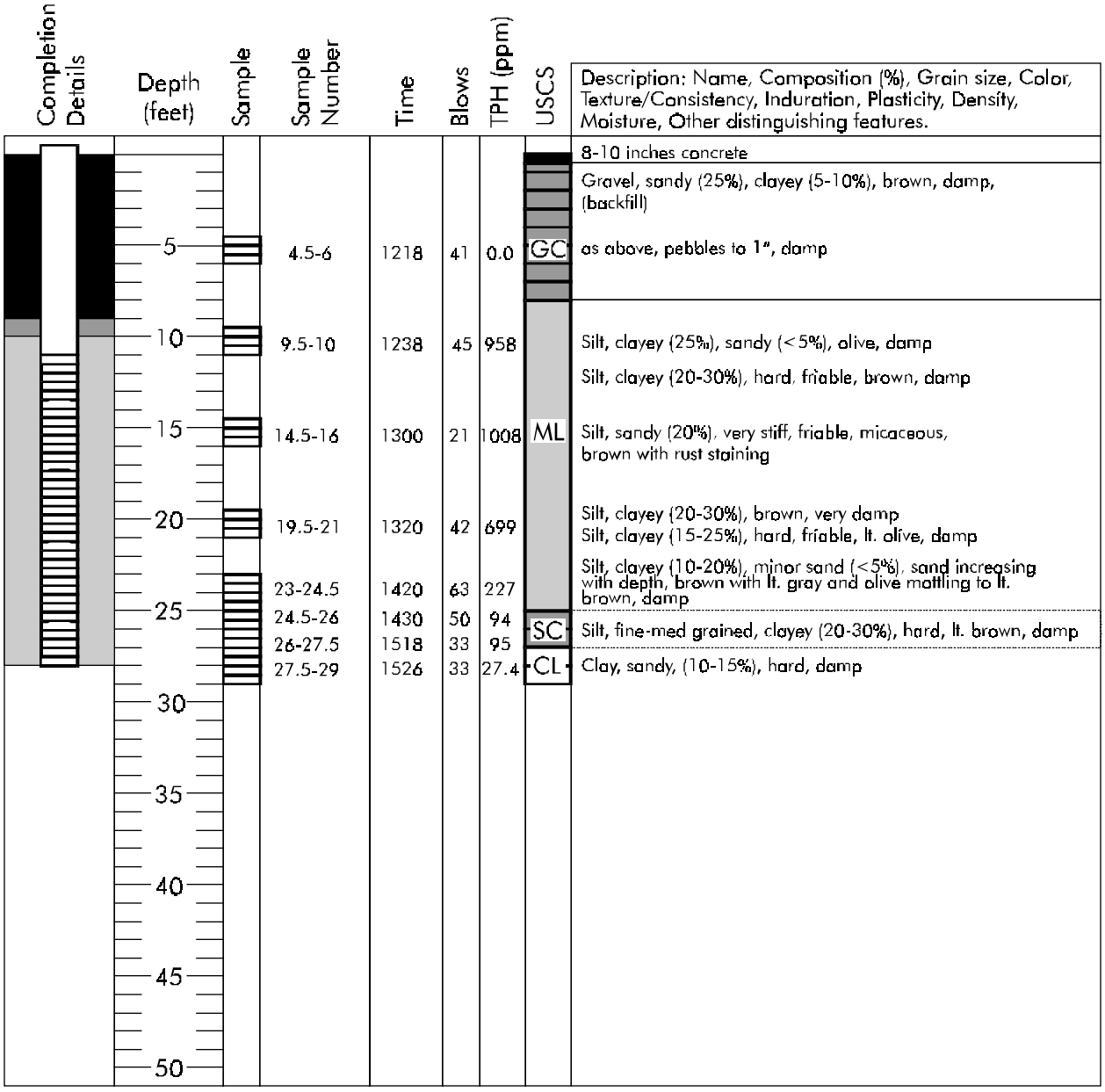
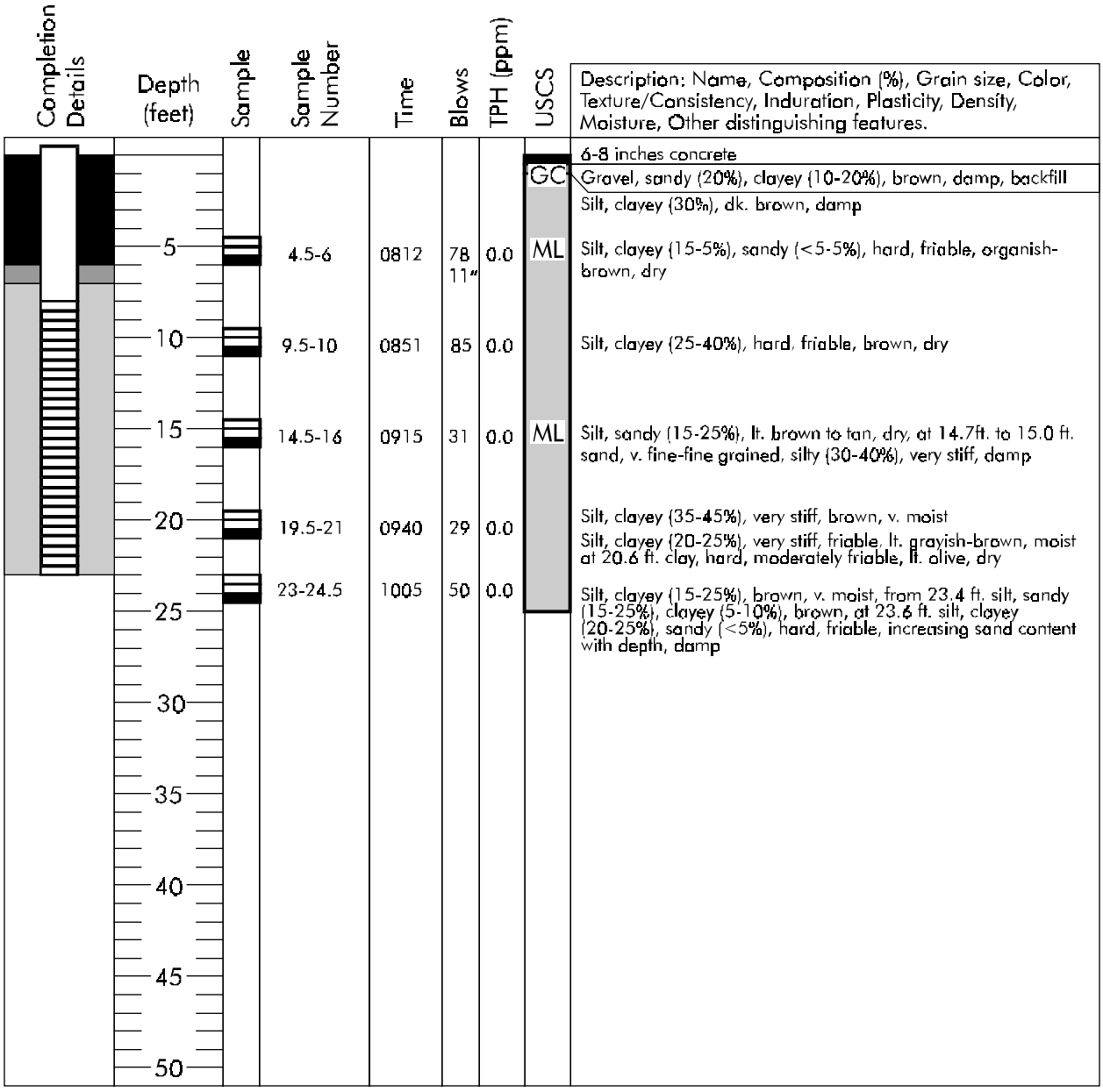
APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-4
Date Drilled: 7/17, 20/92



APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-5
Date Drilled: 7/20/92



APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-6
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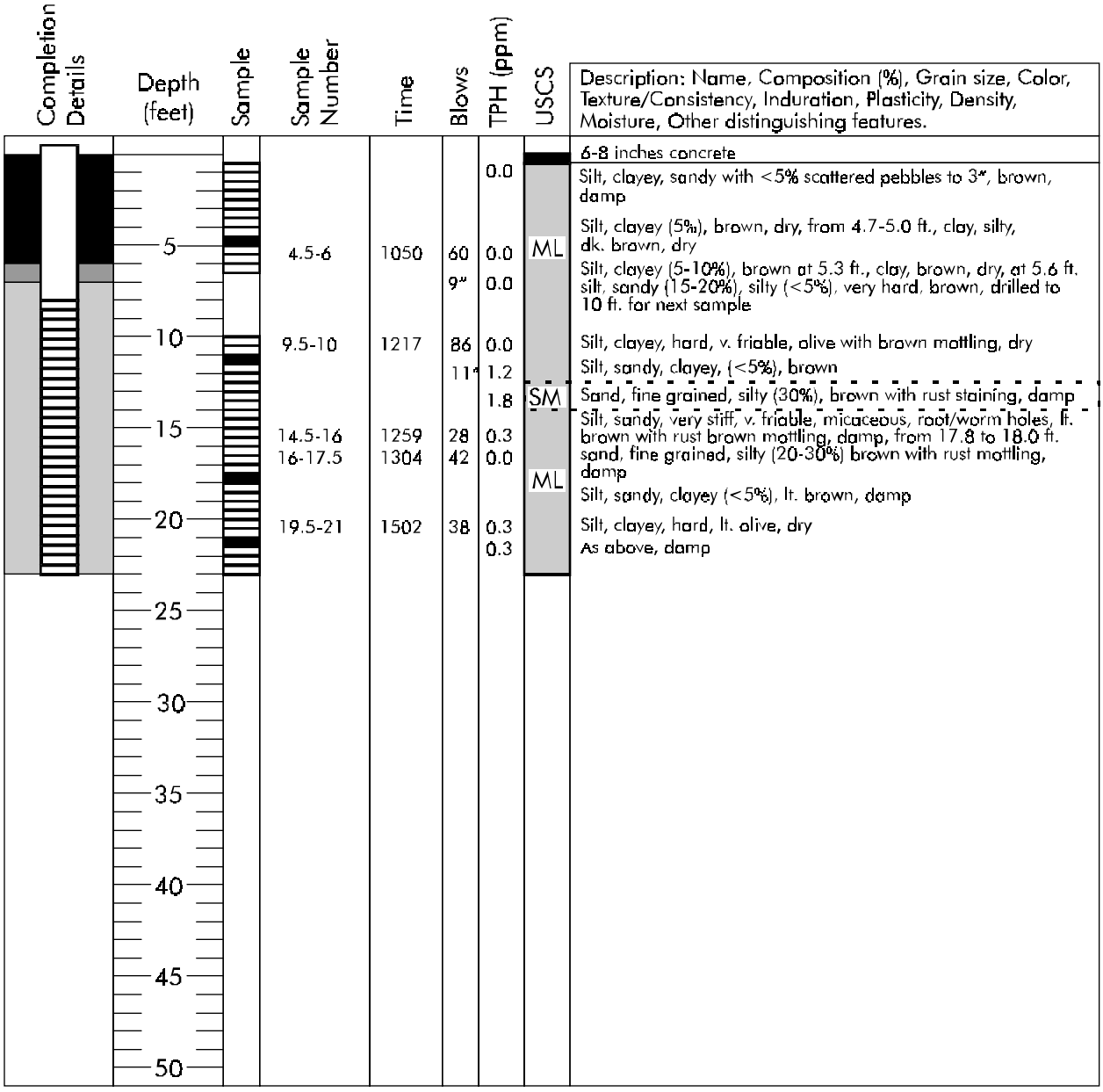

APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-7
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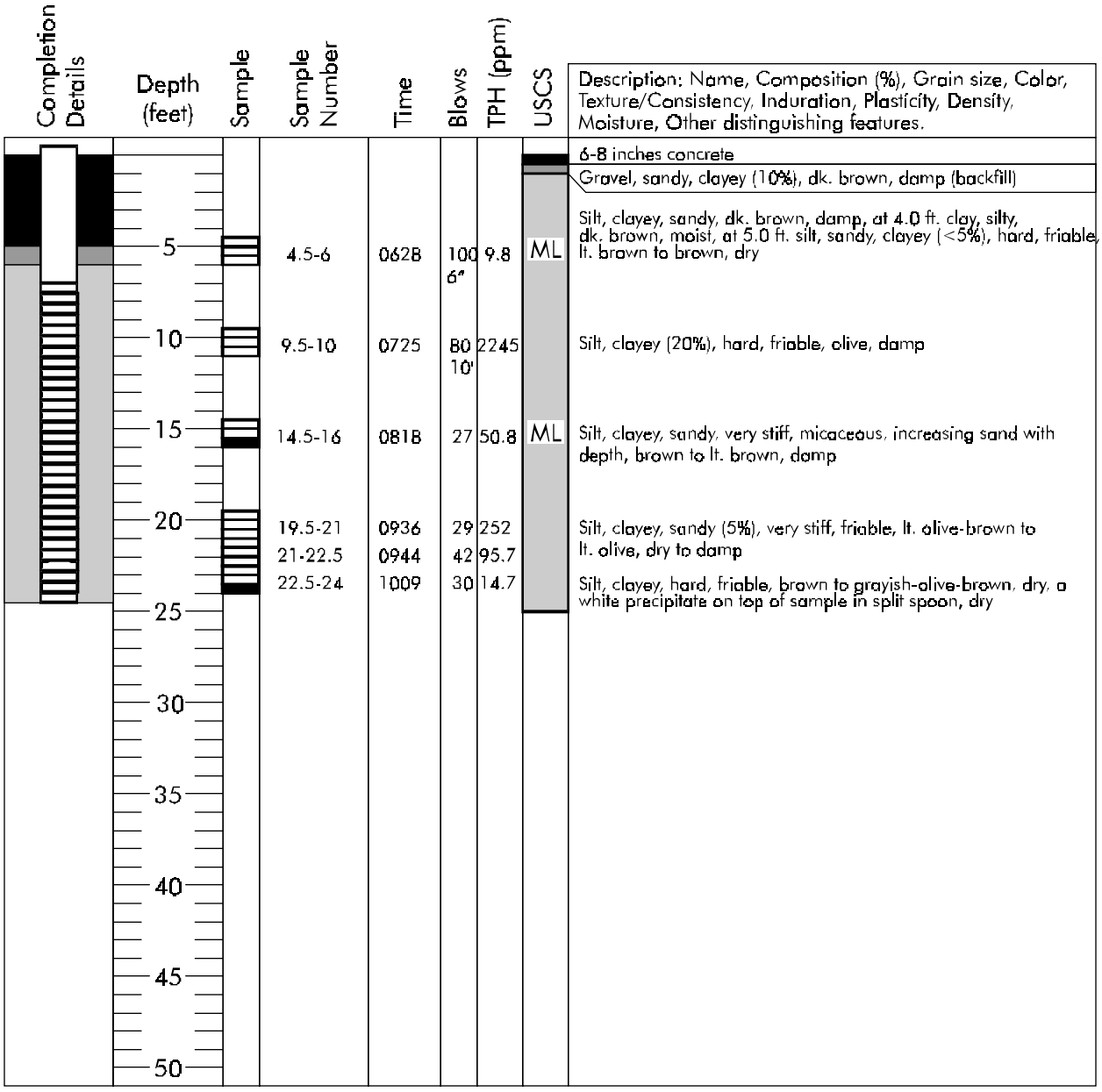

APPENDIX B—BORING LOGS FOR WELLS VE-3 THROUGH VE-8

Boring Well Number: VE-8
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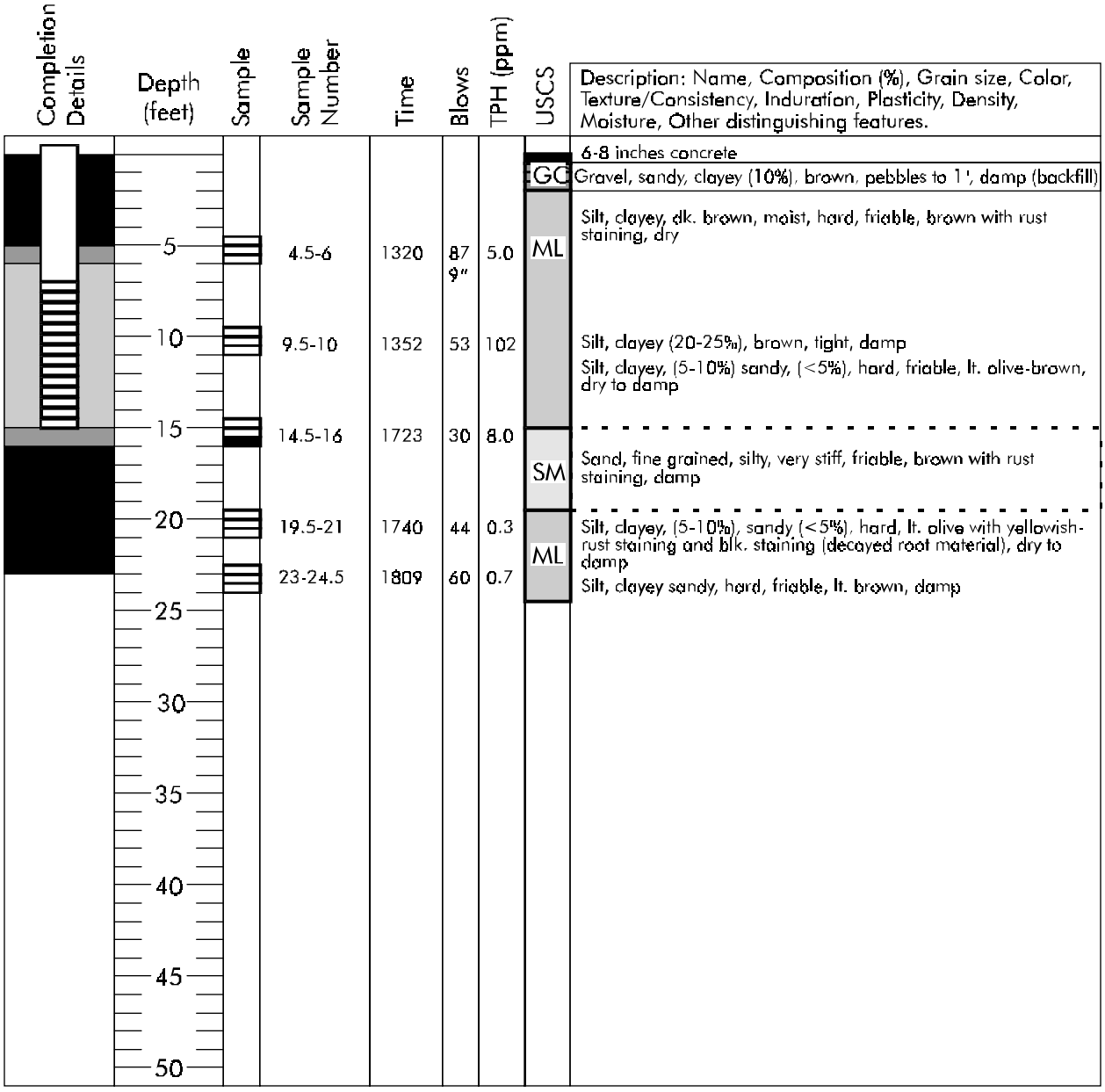

COST AND PERFORMANCE REPORT

Soil Vapor Extraction at the Sacramento Army Depot Superfund Site, Tank 2 Operable Unit Sacramento, California

Prepared By:

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office

March 1995

Notice

Preparation of this report has been funded wholly or in part by the U.S. Environmental Protection Agency under Contract Number 68-W3-0001. It has been subject to administrative review by EPA headquarters, Sacramento Army Depot staff, and the technology vendor. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.